NATURAL RESOURCES MANAGEMENT PLAN

HAWAII VOLCANOES

NATIONAL PARK

HAWAII

UNITED STATES DEPARTMENT OF THE INTERIOR / NATIONAL PARK SERVICE

DEPARTMENT OF THE INTERIOR

NATURAL RESOURCES MANAGEMENT PLAN

Hawaii Volcanoes National Park
Hawaii

REVISED: JUNE 1978

PREPARED BY
HAWAII VOLCANOES NATIONAL PARK
NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

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ENVIRONMENTAL REVIEW
Natural Resources Management Plan and Fire Management Plan
(1978 Revision)

The Hawaii Volcanoes National Park Natural Resources Management Plan is a composite plan of biological research, propagating rare and endangered plant and animal species, reintroducing rare plants into former range, protecting rare endemic biota from depredation by species introduced by modern man, managing wildfires and providing avenues for public knowledge of these unique Hawaiian ecosystems.

Proposed actions. Specific management actions are designed to conserve and perpetuate endemic Hawaiian biota and where feasible minimize or eliminate non-native influences. These actions, with the exception of fire management have been underway for several years and covered in Hawaii Volcanoes Natural Resources Management Plan Final Environmental Statement (FES 74-28) which was approved in 1974. This revision contains updating and some minor modifications of the original proposal as summarized below:

Action	How Changed From Original Plan
I. Re-establish endemic Hawaiian species into former range.	
Plants--	Plant lists have been revised to reflect current information received from botanists and others.
Birds--	Endangered status of birds revised to reflect current U.S. Fish and Wildlife Service designation. Nene project updated and more specific proposal for the alala has been included.
II. Protect remnant Hawaiian ecosystems from exotics introduced by man.	
Goats--	no change
Pigs--	no change
Other Exotic Mammals--	no change
Control Exotic Plants--	Two species, Castor Bean and Ironwood added to control list.

Fire management section is new with this revision. It specifies, on an ecosystem basis under what conditions wildfire is to be managed to perpetuate native Hawaiian ecosystems, and protect life and property. A separate environment assessment on this action has been prepared and is appended to this plan.

Certain structures, buildings and land areas in the park are listed in the National Register of Historic Places to which the procedures of the Advisory Council on Historic Preservation (36 CFR part 800) apply. By letter of December 24, 1974 the State Historic Preservation Officer documented his review of Hawaii Volcanoes Natural Resources Management Plan. The 1978 revision does not materially alter matters considered by him in 1974.

Impacts. Overall impacts of the plan will be to allow native Hawaiian organisms and ecosystems to operate under much less influence and destruction from species introduced by modern man. Goat and pig populations will progressively decrease. A woven-wire fence will enclose much of the park. Nene (Hawaiian goose) should become more common. Certain competitive exotic plants will become less abundant. Many native plant species will increase in density. Ecological studies of natural succession may be more complicated as a result of plant reintroductions and exotic plant control. Response to wildfires will be more deliberate and consistent with park objectives.

Alternatives. An alternative to the overall proposal is to change park objectives from "preserving and restoring native ecosystems" to "conserving all living things in an environment where natural processes are dominant and free of man's intervention." Under this objective all the proposed actions would be unnecessary.

Specific alternatives to each proposed action are numerous and are detailed in the original environment statement and fire management assessment. Alternatives to plant reintroduction range from no-action to greatly expanding the variety and numbers of species to be planted. Alternatives to controlling goats and pigs range from no-action to using poisons. Fire management alternatives include using controlled burns as a management tool, aggressively using bulldozers, and no-action.

Conclusion. Except for the fire management section, all proposed actions of this revision have been subjected to public review during the development of Natural Resources Management Plan Final Environment Statement FES 74-28 and are presently being implemented. In the preparation of the fire management section and its environmental assessment, input from a variety of sources was received particularly from botanists and foresters working in Hawaii. Because none of the proposed fire management actions involved significant impacts to the environment, it is recommended that the Natural Resources Management Plan, Hawaii Volcanoes National Park be assigned a negative declaration. Unless significant controversy develops during public review, a complete environmental statement will not be prepared for the fire management proposal and will be translated into an action program when the 30-day review period has expired.

2/2/78
Date

Superintendent, Hawaii Volcanoes

6/20/78
Date

Regional Director, Western Region

DESCRIPTION OF THE PLAN

The natural history resources of Hawaii Volcanoes National Park are an extensive and exceptional remnant of Hawaii's native biota. The islands' isolated biologic life is duplicated nowhere else on earth. Though these ecosystems are well on their way to massive destruction with continuing extinctions of many Hawaiian species, there are opportunities at Hawaii Volcanoes National Park to preserve and restore a sample of natural Hawaiian biota including representative major vegetation communities from the 13,680-foot summit of Mauna Loa to the sea.

To that end, this resource proposal is a composite plan of biologic research, propagating rare and endangered plant and animal species, reintroducing rare species into former range, protecting rare endemic biota from depredation by species introduced by modern man, managing wildfires, and providing avenues for public knowledge of these unique Hawaiian ecosystems.

The plan is also aimed at fulfilling applicable Congressional mandates for a natural category national park. Authority for the various aspects of the plan is found in the enabling legislation for Hawaii National Park, "National Park Service Administrative Policies" and Title 36, "Code of Federal Regulations."

The plan was also guided by and concurs with the concepts of resources management presented in the Hawaii Volcanoes National Park Master Plan. Pertinent to the park's natural history resources, the master plan states the following park objectives:

> Conduct and encourage natural history research focused upon (1) further definition and insight into the park's native island ecosystems, (2) developing life history and ecologic understanding of species facing extinction; and developing management strategies for preserving endemic island ecosystems.
>
> Preserve the evolving natural scene by protecting outstanding geologic features, such as the calderas and rift zones, steam and sulphur banks, the profile of Mauna Loa, and the associated native ecosystems.

Re-establish the park's endemic species into their former ranges, concentrating efforts on those species which are in danger of extinction, and those that are key components of major native ecosystems.

Protect the park's remnant Hawaiian ecosystems--including endangered species--from further depredation and competition by those exotic animals and plants introduced by modern man.

Seek legislation to identify the Olaa Tract as a detached portion of Hawaii Volcanoes National Park. Until that is accomplished, manage, preserve, and interpret the tract with objectives suitable for a natural area of the National Park System.

Develop an interpretive program predicated on the three themes of particular significance in Hawaii Volcanoes National Park. The primary story is the active volcanism from which the Island of Hawaii is evolving, as illustrated by the Mauna Loa and Kilauea Volcanoes. The story of the native ecosystems and the threats to their survival resulting from introduced plants and animals is second in importance to the geologic story. Another secondary theme will be prehistoric and historic events.

The natural resource actions now underway, and those proposed, are summarized under broad headings as follows:

I. Reestablish endemic Hawaiian species into former range.

A. Plants that are key components of major native ecosystems.

Mamani, naio, 'ohi'a, and koa are raised from seed in greenhouses at Kilauea Headquarters and the Ainahou Ranch for use in planting along such developed and spoiled areas as road cuts, restored building sites, and damaged areas. Some 2,500 seedlings and transplants of these species are planted annually. Additionally, over a 5-7 year period about 10,000 seedlings of mamani are being planted on the recently acquired Ainahou Ranch and within goat-free enclosure units. Approximately 15,000 acres of potential lowland mamani forest are being planted on defined areas representing 50 percent of the potential lowland mamani shrub forest areas. Unplanted zones within the suitable potential sites are deliberate--to allow research opportunity to assess vegetation responses on goat-free areas without the variable of planting programs.

Pili grass seed is broadcast at specific lowland sites to restore damage by construction and fire suppression lines in an attempt to thwart invasions by exotic grasses. These have been ongoing projects for many years but have been expanded into the Ainahou Ranch and the newly constructed goat exclosures.

Table 1. Planted species that are key components of major native ecosystems.

Plant	
koa	Acacia koa
māmani	Sophora chrysophylla
'ōhi'a	Metrosideros collina
naio	Myoporum sandwicensis
pili grass	Heteropogon contortus
lama	Diospyros ferrea
alahe'e	Canthium odoratum

B. Rare plants known to occur (or to have occurred) within the park.

The following plants are raised in greenhouses at Kilauea Headquarters and the Ainahou Ranch (see Table 2). Approximately 10,000 seedlings will be raised each year and planted on defined areas within the exclosure units and other goat-free areas.

As former habitat of these plants is relieved from destruction by goats, excellent opportunity exists for native Hawaiian plant communities to reestablish themselves. In the case of the species listed, it is doubtful that a natural seed source is still present. These species will be planted in park areas that by soil and climate conditions appear to fall within the species former range. This is a program which is totally dependent upon building and maintaining goat fencing and reducing remaining goat populations.

The number of plants managed in this manner will be reduced as species are successfully reestablished and their survival appears secure. It will be expanded to include additional plants that continuing research identifies as rare and endangered, and for which suitable park seed sources are available.

Reintroduction of rare plants into former ranges will be accomplished with care. A variety of local

Table 2. Rare plants known to occur (or have occurred) in the park that are being raised and planted.

Plant		Propagating Material Source	Approx. Acreage Subject to Planting
-	* Adenophorus periens	None now	?
Kauila	* Alphitonia ponderosa	Kipuka Nene, Poliokeawe Pali	10,000
hame	Antidesma pulvinatum	Naulu Forest	1,000
silversword	* Argyroxiphium kauense	Kapapala Ka'u 1/	1,000
-	** Asplenium fragile var. insularia	None now	?
koko'olau	* Bidens skottsbergii var. skottsbergii	Hilini Pali Road, Ainahou	1,000
'ahakea	* Bobea timonioides	Naulu Forest	1,000
'awikiwiki	* Canavalia kauensis	Kukalauula Pali and Kaone	100
kolomona	Cassia gaudichaudii	Kalapana Dry Forest	100
Pāpala	Charpentiera obovata	Kipuka Puaulu	100
'ōhā-kēpau	* Clermontia hawaiiensis var. hawaiiensis	Crater Rim near Thurston Lava Tube	100
-	* Clermontia peleana	None Now	?
-	** Cyrtandra giffardii	None Now	?
-	** Cyrtandra ramosissima	None Now	?
'a'ali'i	* Dodonaea eriocarpa var. skottsbergii	None Now	?
kilioe	Embelia pacifica	Kipuka Puaulu	10
wiliwili	* Erythrina sandwicensis	Wahaula, Kamoamoa, Makahanu	1,000
hau-kuahiwi	* Hibiscadelphus giffardianus	Kipuka Puaulu	100
-	* Ischaemum byrone	None Now	?
kāmakahala	* Labordia baillonii	None Now	?
kāmakahala	* Labordia hedyosmifolia var. kilaueana	None NOw	?
kāmakahala	* Labordia hedyosmifolia var. magnifolia	None Now	?

Table 2. Rare plants known to occur (or have occurred) in the park that are being raised and planted (continued).

Plant		Propagating Material Source	Approx. Acreage Subject to Planting
'oloa	* Neraudia ovata	Halfway House 3,000 ft. (?)	10
'aiea	* Nothocestrum breviflorum	Napua Trail, Kipuka Ki	100
'aiea	* Nothocestrum longifolium v. rufipilosum	Kipuka Ki	100
kulu'ī	** Nototrichium sandwicense v. macrophyllum	Hilina Pali	1,000
pololoi	* Ophioglossum concinnum	None Now	?
hōlei	* Ochrosia sandwicensis	Kipuka Puaulu (Not orginal source)	100
manena	Pelea hawaiiensis v. gaudichaudii	Kipuka Puaulu	10
pelea	Pelea puauluensis	Kipuka Puaulu	10
pelea	Pelea radiata	Kipuka Puaulu	
pelea	* Pelea zahbruckneri	Kipuka Puaulu	10
	** Peperomia expallescens v. brevipilos	None Now	?
	** Peperomia lilifolia v. obtusata	None Now	?
hō'awa	Pittosporum hosmeri	Kipuka Puaulu	1,000
'a'awa-hua-kukui	* Pittosporum hosmeri v. saint-johnii	?	?
hō'awa	** " terminalioides v. macropus	Kipukas Puaulu and Ki	100
hala pepe	* Pleomele aurea	Poliokeawe Pali	1,000
	** Portulaca hawaiiensis	None Now	?
'ihi-makōle	* Portulaca sclerocarpa	None Now	?
loulu palm	Pritchardia beccariana	Ola'a Tract	100
loulu palm	Pritchardia affinis	Kaimu beach 1/, Punalu'u 1/	100
hao	* Rauvolfia remotiflora	Poliokeawe Pali, Wahaula	1,000
ohe makai	* Reynoldsia hillebrandii	Poliokeawe Pali, Kamoamoa Pali	1,000

Table 2. Rare plants known to occur (or have occurred) in the park that are being raised and planted (continued).

Plant			Propagating Material Source	Approx. Acreage Subject to Planting
'ili-ahi		Santalum ellipticum	Poliokeawe, Pali, Pauahi Crater, Tree Molds	1,000
naupaka	*	Scaevola kilaueae var. kilaueae	Hilina Pali Road	10
'ōhai	*	Sesbania tomentosa var. tomentosa	Apua Pt., Halape Trail at 2000'	1,000
	***	Stenogyne angustifolia var. angustifolia	None Now	10
'ohe mauka	**	Tetraplasandra hawaiiensis var. hawaiiensis	Naulu Forest mauka	5,000
ōpuhe		Urera sandwicensis	Kipuka Puaulu	?
maua		Xylosma hawaiiensis var. hillebrandii	Naulu Forest	10
a'e	*	Zanthoxylum dipetalum var. gemincarpum	Kipuka Puaulu	100
a'e	**	Zanthoxylum hawaiiense var. citriodora	None Now	100
	**	Zanthoxylum mauiense var. anceps	None Now	?
kou		Cordia subcordata	Halape	100
'ōhelo		Vaccinium pahalae	None Now	?
koko'olau	*	Bidens skottsbergii var. conglutinata	None Now	?

* Candidates for listing as endangered species
** Candidates for listing as threatened species
*** May already be extinct

1/ Seed source is not within Hawaii Volcanoes National Park but plant is highly suspected of formerly occurring.

areas will receive plantings--enough to assure survival and potential seed sources of each species. Eighty percent of the park lands (adequate for scientific studies) will be left without plantings. In addition, the following guidelines will lessen the possibility that the planting program will confuse scientific studies or upset Hawaiian ecosystems or their component species:

1. To prevent genetic alteration on hybridization of species, extreme caution shall be excercised to avoid introducing varieties or subspecies to areas in which it is known they do not naturally occur. When possible only propagating materials from the areas designated to be planted will be used. If a particular species to be planted can no longer be found in the planting area, then the nearest source shall be used. Planting seeds directly to locations near the source plant will be used in favor of greenhouse germination for species for which this technique proves to be effective. Every effort will be made to obtain propagating material from as many plants of the same species as possible to preserve the natural genetic diversity of plant species.

2. Planting will be done only in areas that have been grossly disturbed by feral or domestic animals. Areas which have retained their native ecological integrity will not be planted.

3. A planting plan shall be prepared indicating proposed planting areas and propagating material sources. This plan shall be available at park headquarters for review by interested persons. It shall be revised whenever deemed advisable, based on competent authority. Disagreements shall be resolved by requesting opinions from leading botanists and ecologists in Hawaii.

4. Complete records shall be kept on all plantings. This will include voucher plants so species planted will be logged for future verification. Locations of plantings shall be marked on topographic maps and aerial photos. These records shall be available to interested persons on request.

C. Birds

Several birds on the Department of Interior's endangered list occur--or did occur--within the

park. These are the *Hawaiian dark-rumped petrel, *Hawaiian hawk, *nene, *Hawaiian crow, *Hawaii 'akepa, *'akiapola'au and *o'u', **Newell's Manx shearwater and Hawaiian creeper. As endemic Hawaiian ecosystems recover--by the proposals to control exotics and restore endemic plants--there may be opportunity to reestablish rare and endemic birds into former range. We propose the following actions related to these endangered bird species:

*Nene formerly bred throughout the park below alpine areas. There have been eight 1-acre nene breeding pens (woven wire 10 feet high) constructed from Ainahou to Kukalauula. There is currently a captive breeding population of 20 geese which we now maintain in these pens. Offspring produced are permitted to fly free and become established in terrain adjacent to each pen. It is planned to continue with this program with the objective of eventually establishing a self-sustaining population in the wild. Two more breeding pens will be constructed--for a total of 10.

*Dark-rumped petrel formerly bred in the Ka'u Desert and probably near Red Hill on Mauna Loa. It is planned to study the feasibility and strategy for reestablishing breeding colonies in these vicinities. At present, lava flows could easily obliterate the only dark-rumped petrel breeding areas on the Island of Hawaii.

The *Hawaiian hawk and the creeper will benefit from habitat restoration. Populations of these species are adequate to expand into suitable habitats; protection and restoration of environments for these species are crucial.

Populations of *ou, *'akepa, and *'akiapola'au are so low that priority efforts are planned for habitat protection and restoration in areas near remnant populations of these species. Studies aimed at life history knowledge and development of strategies for reintroducing birds into former ranges are programmed.

The remnant population of *Hawaiian raven crow (alala) is too far removed from the park to naturally repopulate this area even with restored park habitat. It is planned to seek assistance of the Fish and Wildlife Service and the Hawaii Division of Fish and Game for a reintroduction project. It is proposed to salvage

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*Endangered species
**Threatened species

individual crows that are highly unlikely to survive in the wild because of disease, injury, etc., and raise and breed them in the existing alala aviary located next to the Mauna Loa Field Station. As the project progresses, we also propose to construct six breeding-release enclosures in restored habitat of Kipuka Puaulu-Kipuka Kulalio area. They will be approximately 40' x 20' and built to blend with the landscape and utilized natural vegetation of each specific location selected. Offspring produced therein will be permitted to fly free and gradually be acclimated to surrounding habitat. The element of the plan is contingent upon permit approval from the Fish and Wildlife Service.

II. Protect remnant Hawaiian ecosystems from exotics introduced by man.

A. Goats.

It is planned to continue to control the numbers and distribution of goats to a degree that endangered Hawaiian plants can survive and become reestablished on their former range within the park. Actions supporting this objective are:

1. Reconstruct on a 25-year rotational basis and maintain 50 miles of existing boundary fence. (Fig. 1) To prevent movement of goats into the park from adjacent ranch lands. This fence directly affects all other components of the proposed plan; other actions are fruitless if new infiltration of feral goats from outside the park are not prevented.

   Fence is 4 feet high hog wire fence strong on T-type steel posts placed 15 feet apart.

   Fencing specifications are: woven wire fence, CF&I 1047-6-12-1/2 and post T-type, painted hot rolled carbon or rail steel 1/8 inch thick. Between posts on uneven terrain anchor wire of #8 gauge wire will be installed. Fence must have less than a 4-inch gap with the ground. Fence right-of-way is not to be levelled or bulldozed. Fence is to follow the lay of the land so that the land surface remains undisturbed, and archaeological sites will be avoided. Old fence is to be removed from the site.

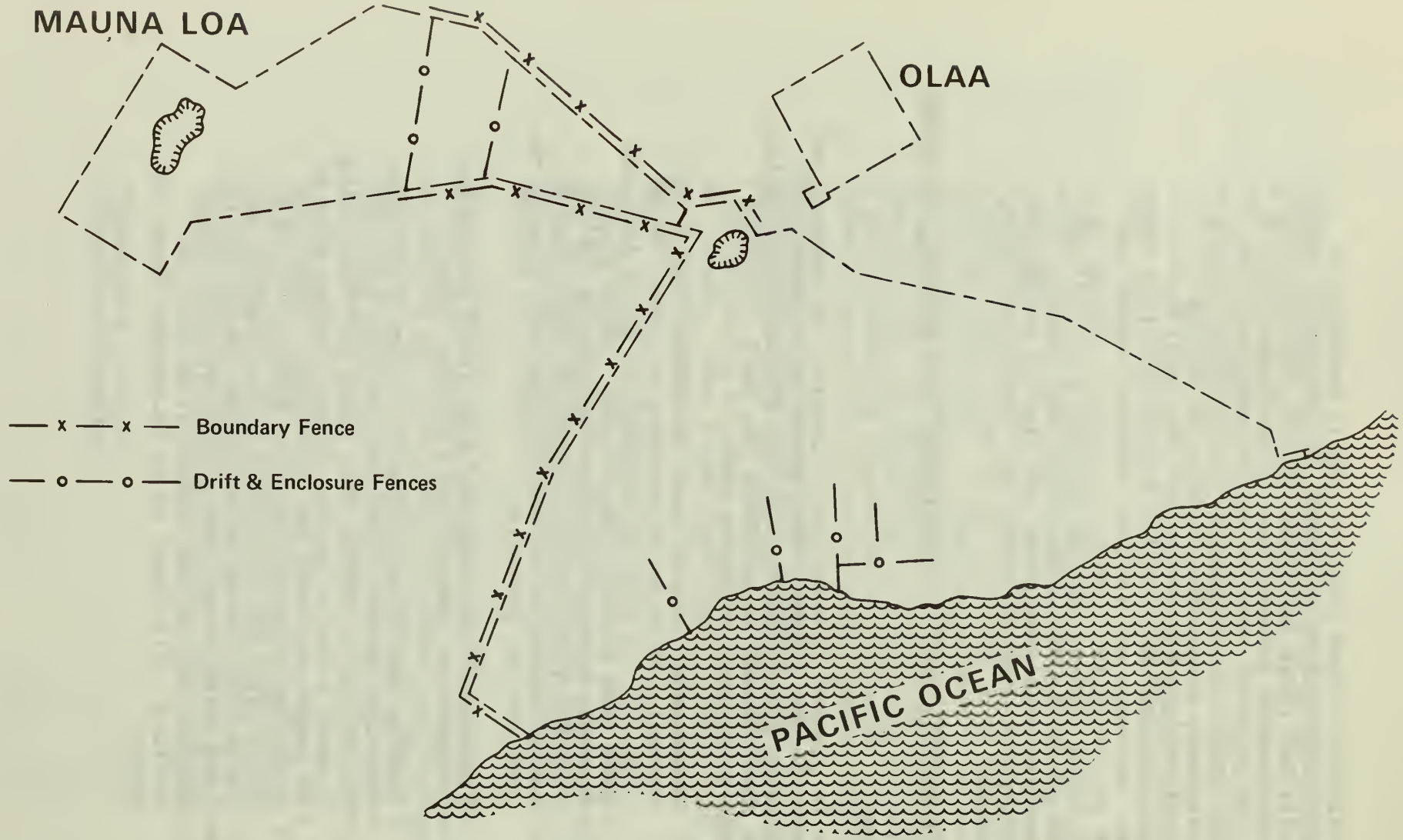


Fig. 1 - Fences to be maintained for goat control.

2. Maintain 20 miles of drift and exclosure fence (Fig. 1) To exclude goats from critical endemic plant areas and to assist in goat control measures. These fences directly affect the success in saving remnant plant species from extinction and efforts to reintroduce these species into their former range. The fencing is similar to item 1 above except that the vertical stays are 12 inches apart (CF&I 1047-12-12-1/2).

3. In areas where effective, remove goats from the park by means that allow local citizen participation in the reduction and disposal of excess goats. This effort will continue as long as the people show interest in the program. Citizens are deputized as park rangers for purposes of goat control. They kill or capture goats in areas and at times designated by the park superintendent, and act under control of park rangers. It is anticipated that goat populations held to a low enough level for endemic Hawaiian plants to flourish will be too small to interest citizen goat hunters.

4. In areas where feasible, remove goats from the park by drives and roundups conducted by park personnel. Live goats so captured will be sold to public bidders.

5. Where other means are insufficient or impossible, park personnel will be assigned, using trained goat dogs to hunt and kill excess goats.

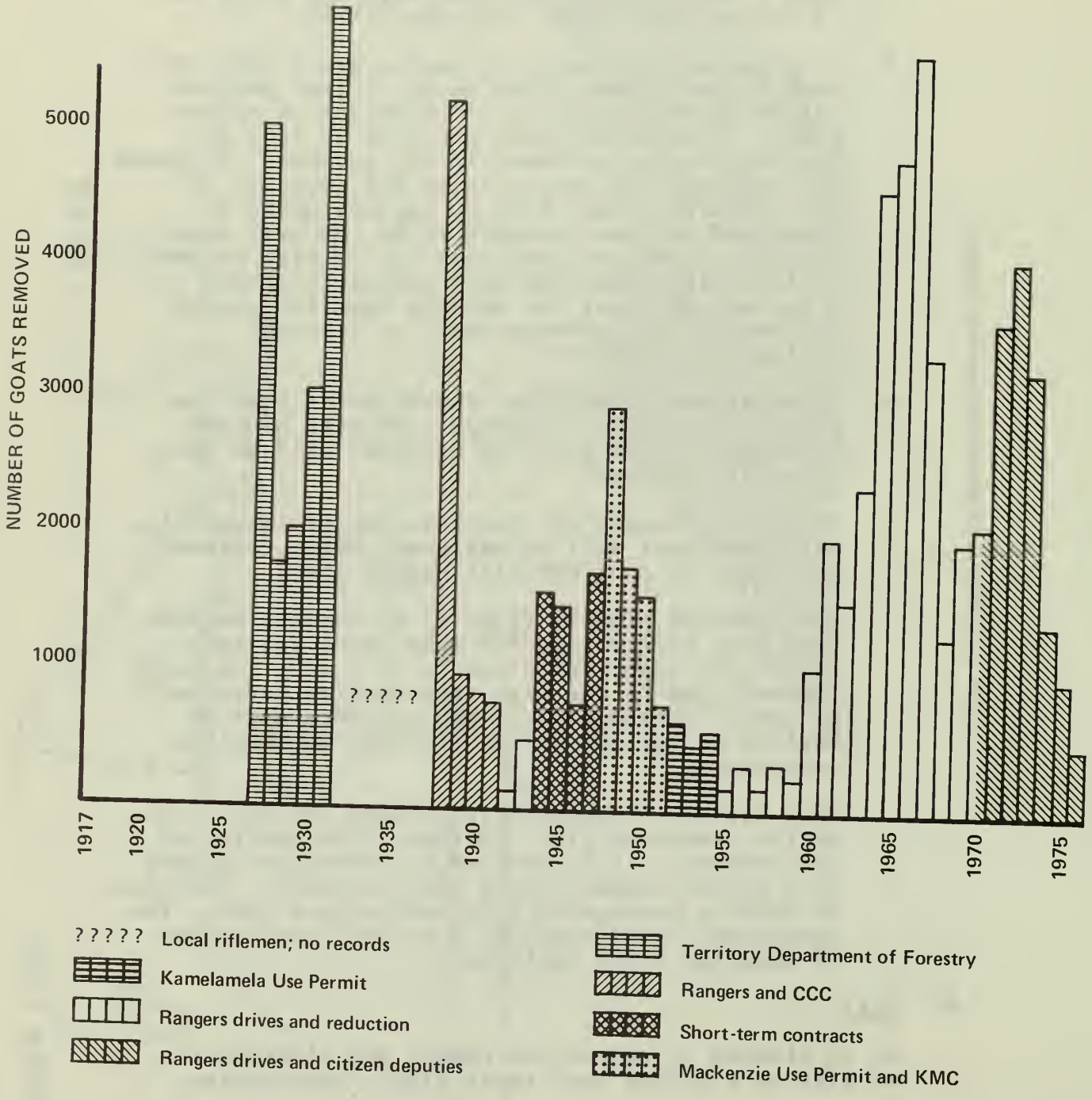
Goat removal efforts (Fig. 2) by various methods have been progressing for many years and as a result the goat population is at a very low level. However, due to the high reproductive potential of goats, constant vigil and pressure must be applied to curtail any destruction to Hawaiian ecosystems.

Goat control proposals listed here are key to the entire resources plan. Without this portion of the proposal, it is useless to transplant plants into former ranges--goats eat the plants. Efforts to restore endangered bird populations (nene, the drepanids, crow) are futile without restoration of Hawaiian plant habitats.

B. Pigs.

It is planned to reduce the number and distribution of pigs to a degree that their effect upon native

Fig. 2 - Number of goats taken annually from Hawaii Volcanoes National Park.



Hawaiian vegetation is minimal. Actions to effect this are:

1. In areas where effective, remove pigs from the park by a means that would include local citizen participation in the reduction and disposal of excess pigs. Deputize citizens as park rangers for the purposes of pig control. Using dogs, they will kill or capture pigs in areas and at times designated by the park superintendent, and act under control and direction of park rangers. This program began in fall 1972 and will continue as long as citizens show interest by their participation.

2. Assign park personnel to hunt and kill excess pigs. This is ongoing and will continue.

3. Research various pig population control measures. Using the remote Napau Crater area as a research area, carefully controlled studies in pig populations and various pig control measures will be undertaken. Studies will continue for about 5 years, and should form the basis for an effective effort in pig population control.

While pig removal efforts have been continuing for many years (Fig. 3), they have been inadequate to prevent pigs from rooting and destroying native Hawaiian vegetation. Pigs eat and spread seeds of exotic plants. Guava is largely spread by pigs. Control of exotic plants and protection of rare native plants is impossible without greater control of feral pigs.

C. Rats and Mongooses.

Rats and mongooses have done inestimable damage to endemic island biota. The destruction is continuing; yet, there is no present knowledge or technology available on which to base a park-wide plan of effective rat or mongoose population control. Therefore, no broad-scale control efforts are contemplated at this time.

The following management efforts are planned:

1. Research aimed at better definition of the damage rats and mongooses are doing to native ecosystems (including rare species) and population control measures.

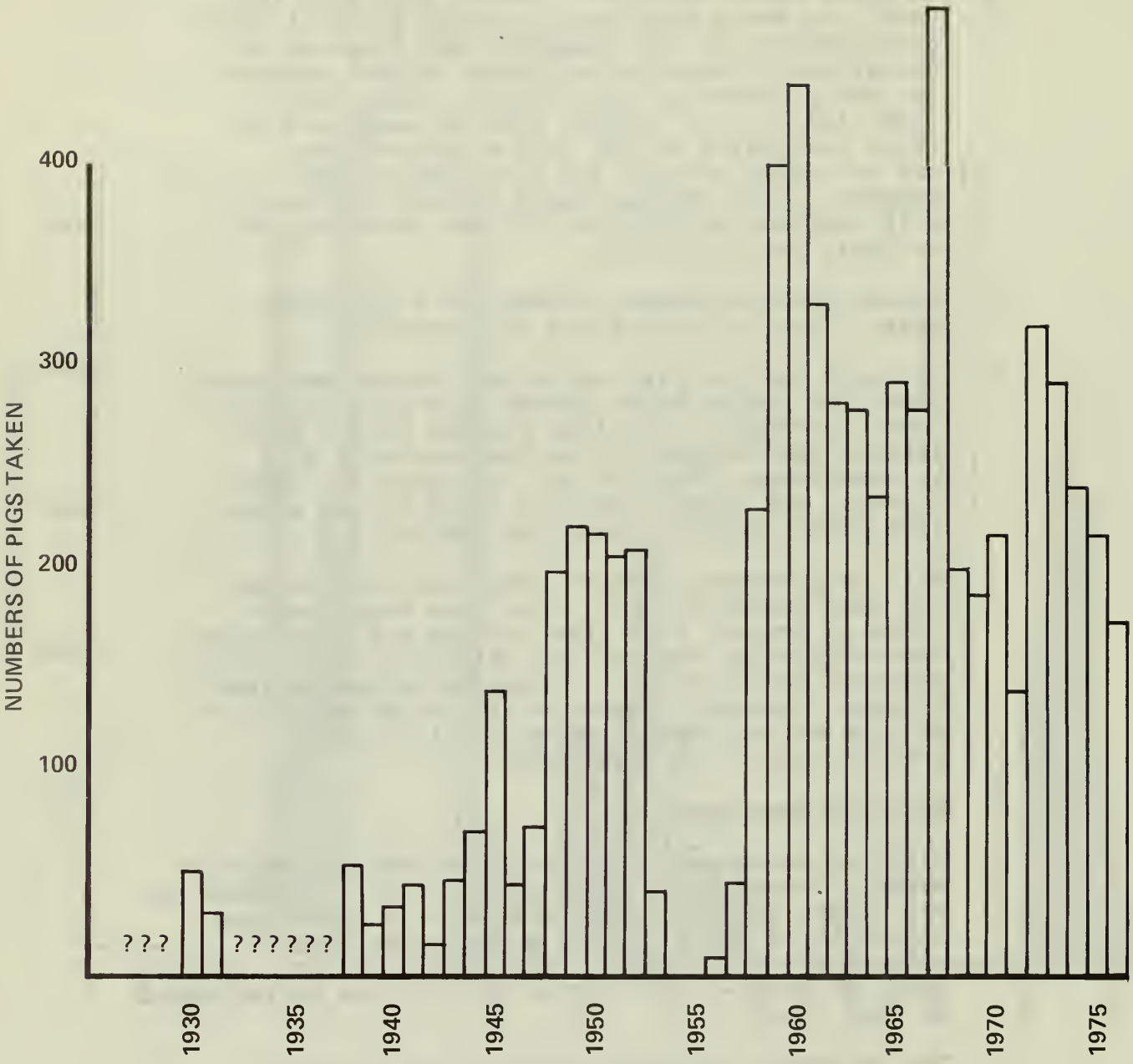


Fig. 3 - Number of pigs taken by all methods in Hawaii Volcanoes National Park, 1927 to 1976.

2. Specific control efforts at localized areas limited to nesting sites of dark-rumped petrel and Newell's Manx shearwater and in vicinity of the breeding pen experiments with nene. This control involves both live trapping and local, specific use of the poison Warfarin.

3. Control of backcountry garbage disposal to reduce habitat for rats at such places as Red Hill Rest House (which is adjacent to a former nest site of dark-rumped petrel).

D. Other Exotic Mammals.

Trespass cattle and sheep (and at times burros), cats and dogs pose a continuing problem in feral animal control. Populations are low but require perpetual efforts at fence repair, trapping and shooting, to keep effects of these animals to a minimum.

E. Control of Exotic Plants.

More than 400 exotic plants are recorded within Hawaii Volcanoes National Park. At present, several of these (Table 3) give cause for alarm because of their potential to take over widespread areas and cause major vegetation-type shifts away from native plant systems. This is particularly true in areas where goats and pigs eat the native plants. Two general techniques are used to control these plants:

1. Cut individual plants and apply approved herbicides such as Kuron, Karmex, or Dalapon to individual stems.

2. Cooperate with the State Department of Agriculture in finding natural biologic enemies for certain of the problem species. For example, State introduction of insects--lantana defoliater, Hypena strigata; leaf miner, Cremastobombycia lantanella; beetle, Octotoma scabrinpennis; and moth, Uroplata girardi--have been effective in impeding spread of the exotic shrub Lantana.

   It is anticipated that problems with exotic plants will be less when goat and pig populations are controlled.

F. Fire Management.

Natural and man-caused fires are a recurring significant influence on park resources. It is proposed to

manage these fires through planned actions designed to achieve the following objectives:

1. Prevent loss of human life and property.

2. Prevent damage to property of adjacent landowners.

3. Maintain and provide for the restoration of native Hawaiian ecosystems.

4. Protect significant biological features such as endangered plants, native bird habitat and unique biotic communities.

Fire management shall be conducted from an ecosystem standpoint (Fig. 1A, Appendix). Based on current knowledge and experience in Hawaiian fire ecology, fire prescriptions by units (Table 1A, Appendix)--defining what response or action will be taken should a fire break out--have been developed to guide fire control personnel.

As a general concept, direct fire suppression will be accomplished with a minimum damage to natural park features, e.g., bulldozers if needed will be used with discretion; potential damage to resources from fire will be weighed against potential damage by fire fighting activities; naturalness of fire operating in the ecosystem will be continually evaluated; where possible, natural fire barriers--lava flows, stream channels, palis and cliffs--will be used as fire control points.

All man-caused fires if still confined to a relatively small area--campsite, picnic area, road or trailside patch, will be extinguished with all possible haste. Once such a fire becomes relatively large (requiring more than just immediate attack strategy) it will come under the dictates of this plan.

Information on the effect of fire and the associated role of exotic plants on native ecosystems is wholly inadequate for management needs. Fire oriented research will be supported and encouraged. As new information becomes available, this plan will be reevaluated in that light so as to insure that proposed actions do in fact contribute to park objectives.

Table 3. Exotic plants in Hawaii Volcanoes National Park that have high potential to take over Hawaiian ecosystems.

Name	Approximate Acreage Now Involved	Potential Acreage Involved	Control Technique Underway
Andropogon grass (*Andropogon sp.*)	25,000	60,000	No direct control
Guava (*Psidium cattleianum*) (*Psidium guajava*)	10,000	50,000	Cut and individually poisoned.
Lantana (*Lantana camara*)	10,000	75,000	Biotic control; introduced insect enemy
Christmasberry (*Schinus terebinthifolius*)	1,000	50,000	Cut and individually poisoned.
Silky Oak (*Grevillea robusta*)	500	50,000	Cut and individually poisoned.
Ekoa (*Leucaena latisiqua*)	25	75,000	Cut and individually poisoned.
Tibouchina (*Tibouchina urvilleana*)	200	1,000	Cut and individually poisoned.
Blackberry scattered over (*Rubus penetrans*) (*Rubus ellipticus*)	400	2,500	Spray or cut and individually poisoned.
Faya tree scattered over (*Myrica faya*)	25,000	75,000	Cut and individually poisoned.

Name	Approximate Acreage Now Involved	Potential Acreage Involved	Control Technique Underway
Wild Olive (*Linociera ligustrina*)	500	10,000	Cut and individually poisoned.
Fountain grass (*Pennisetum setaceum*)	1	20,000+	Uprooted and poisoned when found.
Cactus (*Opuntia sp.*)	100	3,000	Individually cut and biological control.
Banana poka (*Passiflora sp.*)	10	2,000	Cut and individually poisoned.
Eucalyptus (*Eucalyptus globulus*)	10	3,000	Cut and individually poisoned. Large trees logged.
Castor Bean (*Ricinus communis*)	20	5,000	Cut and individually poisoned. Large trees logged.
Ironwood (*Casuarina equisetifolia*)	3	50	Cut and individually poisoned. Large trees logged.

CONSULTATION AND COORDINATION

CONSULTATION AND COORDINATION IN THE DEVELOPMENT OF THE RESOURCE MANAGEMENT PLAN

During the preparation and revision of the natural history resource management plan, many sources outside the Park Service were consulted for their knowledge, suggestions, and recommendations. The following list is indicative of the types of sources contracted:

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Goat and pig control; fencing proposals; deputy ranger program:	Hawaii Audubon Society Hawaii Conservation Council Hawaii Island Fish and Game Association Hawaii State Division of Fish and Game
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APPENDIX

FIRE MANAGEMENT PLAN
AND
ENVIRONMENTAL ASSESSMENT

June 1978

HAWAII VOLCANOES NATIONAL PARK

Hawaii 96718

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A. Overview of the Role of Fire at Hawaii Volcanoes National Park

Fire management at Hawaii Volcanoes National Park is concerned with many factors. A rich variety of ecosystems are found within the park, as well as active volcanoes. The indigenous elements of these systems evolved from a few ancestors who reached the isolated islands by chance. Natural wildfires resulting from vulcanism and lightning have been important evolutionary forces which shaped modern species. The park's resources management objectives are based upon the concept of preservation and restoration of native ecosystems. Unfortunately, no ecosystem in the park remains entirely native; in fact some lowland communities contain very few native components. This condition is largely the result of the effects of non-native agents such as goats, pigs and exotic plants, introduced by Polynesian and western man. Resource management activities operate to reduce or eliminate, where feasible, the effects of these agents and to encourage the native elements.

In this context, wildfire may or may not contribute to the attainment of park objectives within specific ecosystems. Evaluation of when, where, and under what conditions fire is a desirable agent to help preserve and restore native ecosystems must be based on the knowledge of the response of native and non-native flora and fauna to fire. Very little research has been conducted on fire ecology in Hawaii. Nevertheless, fires are occurring periodically whether planned or not, and managers are often faced with difficult choices without adequate information to guide them. This plan discusses the various factors making up the local fire environment, characteristics of the major ecosystems of the park, and proposed fire management actions to be taken in light of our present knowledge of fire effects.

B. The Need for a Fire Management Plan

A clear and detailed statement of policy regarding wildfire within the park is needed for the following reasons:

1. To insure that fire policies are in accordance with other park objectives as stated in the Master Plan, Wilderness Plan, and Resources Management Plan;

2. To guide management actions in wildfire prevention and control measures;

3. To avoid or minimize unjustified expenses and unwarranted resource damage during suppression activities;

4. To predetermine, as clearly as possible, the conditions under which some fires may be allowed to burn, and consequences of a lack of control measures in certain circumstances; and

5. To fully inform park neighbors and cooperating agencies of our policies.

C. National Park Service Fire Policy

"The presence or absence of natural fires within a given ecosystem is recognized as a potent factor stimulating, retarding, or eliminating various components of that ecosystem. Most natural fires...are recognized as natural phenomena which must be permitted to continue to influence the ecosystem if truly natural areas are to be perpetuated.

Management fires, including both fires of natural origin and prescribed burns, are those fires which contribute to the attainment of the management objectives of a park through execution of predetermined prescriptions defined in detail.

Natural fire is the preferred means to achieve the prescriptions in natural zones. This use of natural ignition may be adopted when analysis of historic fire occurrence, control, and influence, indicates that natural fuel loading has not been significantly altered by past management or fire control. It may also be used where the prescription provides for a transition from an altered state back to historic fuel loading.

Clearly defined limits will be established in the prescription of all management fires, beyond which limited or complete control action will be undertaken.

Management fires in the park will be suppressed which threaten:

human life,

cultural resources or physical facilities of the park;

threatened or endangered species;

to escape from predetermined zones or from the park, except where cooperative agreements provide for certain fires to cross such boundaries; or

to exceed the prescription.

All fires not classed as management fires will be suppressed.

An active fire prevention program will be conducted in the park in conjunction with other agencies to protect human life, prevent modification of park ecosystems by human-caused wildfire, and prevent damage to cultural resources or physical facilities.

Human-caused fires will be controlled to prevent damage and to eliminate unnatural impact on the park ecosystems.

The fire suppression methods used in the park will be those causing the least resource damage, commensurate with effective control.

Cooperative agreements will be developed to facilitate reciprocal fire control activities within and adjacent to the park.

(U. S. Dept. of the Interior, National Park Service. 1975. Management Policies.)

II. DESCRIPTION OF THE PROPOSAL

Natural and man-caused fires are a recurring significant influence on park resources. We propose to manage these fires through planned actions designed to achieve the following broad objectives:

1. Prevent loss of human life and property.

2. Prevent damage to property of adjacent land owners.

3. Maintain and provide for the restoration of native Hawaiian ecosystems.

4. Protect significant biological features such as endangered plants and native bird habitat, unique biotic communities, etc.

Fire management shall be conducted from an ecosystem standpoint (Fig. 1A). Based on current knowledge and experience in Hawaiian fire ecology, fire prescriptions by units (Table 1A)--defining what response or action will be taken should a fire break out--have been developed to guide fire control personnel.

As a general concept, direct fire suppression will be accomplished with a minimum damage to natural park features, i.e., bulldozers if needed will be used with discretion; potential damage to resources from fire will be weighed against potential damage by fire fighting activities; naturalness of fire operating in the ecosystem will be continually evaluated; where possible, natural fire barriers--lava flows, streams channels, and palis (cliffs) will be used as fire control points.

All man-caused fires, if still confined to a relatively small area--campsite, picnic area, road or trailside patch, etc., will be extinguished with all possible haste. Once such a fire becomes relatively large (requiring more than just immediate attack strategy) it will become under the dictates of this plan.

Information on the effect of fire and the associated role of exotic plants on native ecosystems is inadequate for management needs. Fire oriented research will be supported and encouraged. As new information becomes available, this plan will be reevaluated in that light to insure that proposed actions do in fact contribute to park objectives.

FIRE MANAGEMENT PRESCRIPTIONS BY UNITS TABLE 1A

Ecosystem Type and Brief Description	Prescribed Response
Subalpine 6,700' to 8,500' elevation in the Mauna Loa Strip area. Much barren lava with kipukas containing sparse, primarily native vegetation. Fire potential for ignition and spread is low. Exotic plant influence is nil.	All fires above 8,000' will be observed only but closely monitored. Fire between 6,700' and 8,000' will be observed and closely monitored, but if it appears to threaten adjacent private lands or spread into the montane seasonal ecosystem, it will be contained or suppressed without using bulldozers, if possible.
Montane Seasonal 3,800' to 6,700' in Mauna Loa Strip area. Mountain parkland with koa, ohia, and mamani forests interspersed among dense grasslands and shrublands. Some natural a'a lava fire breaks Highly flammable vegetation during dry periods. Fire potential is high and spreads rapidly. Exotic grasses are widespread but successional trends are to native trees and shrubs. Kipuka Puaulu and Kipuka Ki are irreplaceable biological communities.	Suppress all fires using methods which will do minimal damage to resources. Bulldozer, however, may be used to protect important kipukas and adjacent ranch lands. Bulldozer operations should avoid a'a lava on which old mamani trees grow.
Montane Rain Forest 2,000' to 3,800' elevation, wet ohia-tree fern forest. Fire potential is low and spread rate is slow except during extreme dry periods. Following a fire, invasion of landscape by Andropogon grass is a problem in that it increases fire potential. Successional trends will take it back to native rain forest if fire can be excluded for a long enough period.	Lava-caused fires which do not spread from the edge of the flow will be observed only. All other fires will be suppressed as quickly as possible using methods which will cause minimal damage to the resource. Only under unusual conditions would the use of bulldozers be necessary.

Submontane Seasonal 1000' to 2,000' from Kalapana to the Ka'u boundary. Above Hilina Pali vegetation are ohia forests with grass and shrub understory. Below Hilina and Polio Keawe Palis terrain is mostly grasslands with scattered ohia and lama trees. Numerous natural fire breaks occur throughout the unit. Exotic grasses pose a serious problem. Fires burn hot and grasses quickly reinvade. Old ohia trees die as a result of these grass-fueled fires and there is very little regeneration.	Western Section: (South of Ka'u Desert). If it is expected that fire will be confined to a single kipuka or is burning through primarily exotic grassland with little chance of spread to forested areas, it will be observed only but closely monitored. However, if fire appears to have the potential to burn into forested area, it should be contained or suppressed by fighting it using natural barriers as much as possible. Central and Eastern Sections: Observe and monitor closely unless and until fire spreads from grasslands into forested areas; in which case, contain or suppress using existing natural barriers where possible. Fires which begin in or threaten the forested Ainahou-Kipuka Nene area should be suppressed using bulldozers and other equipment if necessary.
Coastal Lowlands Sea level to approximately 1,000'. Predominately exotic grasslands with scattered ohia trees. Numerous palis and lava flows which act as natural lava barriers. In the absence of goats, successional trends are towards more succulent shrubland species. Fire potential is high and rate of spread is rapid, particularly in the Keauhou, Halape, Kaone area.	Observe only unless and until fire threatens to burn from grasslands into forested areas, then in which case, contain or suppress using natural barriers as much as possible. Suppress all fires in Kalapana area east of Kamoamoa. Use bulldozers if necessary to prevent fire from burning onto private land adjacent to Kalapana boundary.

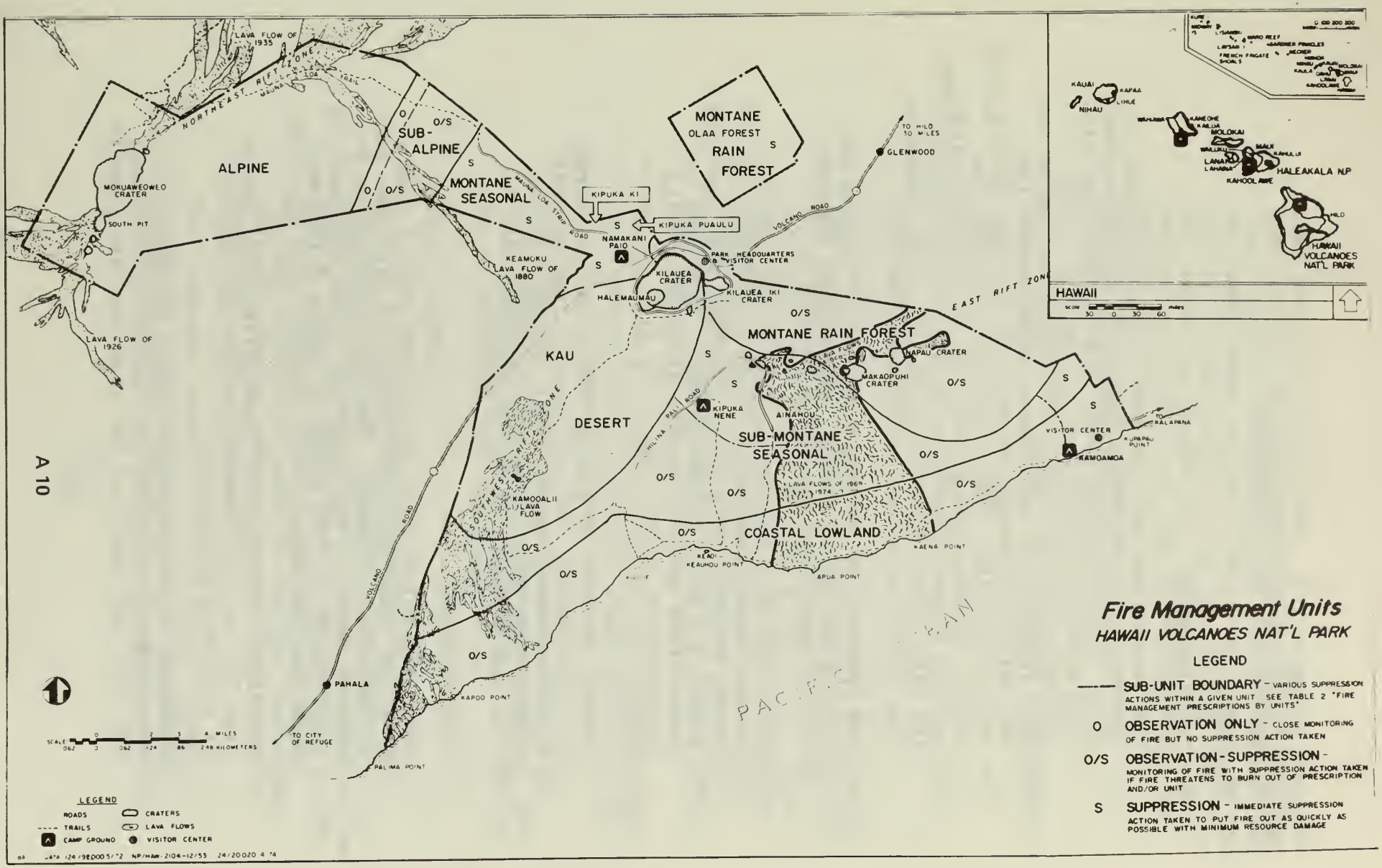

Fig. 1A - Fire management units in Hawaii Volcanoes National Park

III. DESCRIPTION OF THE FIRE ENVIRONMENT

A. Weather

1. Wind Patterns

The trade winds are the most dominant element in the weather patterns at Hawaii Volcanoes National Park. Strong steady flows of moisture-laden air blow across the park much of the year. The trades generally bring daily precipitation to the rain forest. As they become more intense the precipitation becomes heavier in the rain forest and brings light showers further into the lee areas. As the trades cross the divide from windward to leeward they lose much of their moisture. The wind flow continues across the park, becoming ever drier and warmer as it descends.

The presence of a trade wind regime usually dictates a period of stable, predictable patterns of both precipitation and dessication.

The trade wind pattern weakens during the winter. Several times each winter (and less frequently in the summer) low pressure systems move near the Island and bring a southwesterly flow over the park. This usually results in general rains, occasionally rather than heavy (15" in 3 or 4 days).

Periods of weak or absent trades and no storms are less common, but may persist from several days to several weeks. This weather is most significant since it allows drying in areas that are normally cloudy and rainy.

2. Precipitation

Average precipitation in the park varies from over 130" near Makaopuhi Crater to less than 20" at Mauna Loa's summit. The division between wet and dry areas is quite marked. Park Headquarters receives about 100" annually, while Halemaumau, less than two miles away, receives only about 50".

Annual precipitation at headquarters has ranged from 58" to 182". Monthly variation, however, is even more pronounced.

Although winter (November-April) is usually considered the wet season and summer (May-October) the dry, each month of the year may vary greatly

from one year to the next. For example, January 1952 had 30.55" of rain while only 1.20" fell in January 1953. A typical year has several months both well above and well below the average precipitation for each month, in no particular pattern, but amounting to near the 100" average. Precipitation at various locations in the park may be roughly estimated by applying the following percentages to the headquarters figure for the period in question:

	Hq.	Mauna Loa 5,500	Kipuka Nene	Ainahou	Kalapana
Winter	100%	73%	85%	90%	62%
Summer	100%	32%	26%	38%	49%

3. Inversion effects

The temperature inversion is a normal feature of the trade winds. The inversion is most commonly found between 5,000 and 7,000 feet, although it may range from 4,000 feet to 8,000 feet. From sea level to the inversion base the temperature decreases and the moisture increases in a predictable manner. The inversion may then be up to several degrees warmer. With a strong inversion clouds rarely rise above the base.

Beneath the inversion relative humidity averages 70 to 80 percent in windward areas and 60 to 70 percent in leeward percent on down.

The level and strength of the inversion is of critical importance on the Mauna Loa strip. The lower and/or stronger the inversion, the greater the dessication from the base on up.

4. Fuel response

Data on fuel response in the park is lacking. The Forest Service, USDA, in its work on a Hawaiian Fire Danger Rating System, has determined that a fine fuel model is most appropriate to the entire state. A cursory examination of the various vegetation types in the park indicates that fine fuels, either alone or leading to an overstory, are predominant.

Fuel moisture response, then, should generally be thought of as fairly rapid. As an example, in January 1975, a small fire in the community

of Volcano raced across the upper layers of a grassy field. This fire occurred after only one morning of sunny weather following a storm which had dropped over 15" of rain in the preceding days.

5. Lightning

There are three lightning starts known on this island, one of which occurred in the park near Pepeiau in May 1971. Thunderstorms are more common in Hawaii than most residents realize. Since they usually occur inland in less populated areas they often pass unnoticed. The winter months have the greatest frequency of storms. Lightning strikes have occurred occassionally in the park as evidenced by damage to seismograph wires and first hand reports from hikers. The upper Ka'u Desert would appear to be most vulnerable to lightning starts.

B. Fire History

Early travelers in what is now Hawaii Volcanoes National Park were more impressed with volcanoes and Hawaiians than with fires or their evidence. Accounts of historical fires within the park in journals and reports are few in number and lack details.

Records for other parts of this and other islands are incomplete, but do show some characteristics of fire in Hawaii. The average fire is small, often less than one acre in extent. This is attributed to the moisture content and nature of most fuels, and the frequent rains. However, a number of fires of more than one thousand acres have been recorded. A fire in South Hamakua, Hawaii, in 1904 covered an area 15 miles long and 2 to 4 miles wide in ohia-koa-tree fern forests. A fire in 1924 burned 12 square miles of open forest on the slopes of Mauna Loa. Kapapala Ranch, adjacent to the park, had a 3,200-acre fire in 1960 and 3,500 acres burned in the Pahoa region in 1963. Within the park, the Naulu fire covered 3,525 acres in 1972, and the Six Tanks fire burned a total of 2,260 acres in 1975 and 500 acres in 1977. Similar events have occurred on all the other islands.

Many fires, though small, have been persistent when they changed from a surface to a ground fire. A 20-acre fire burned for six days in 1922, and a few years later a 1-1/2 acre fire on Kauai had to be watched for nine days. The Six Tanks fire, in the

Mauna Loa Strip section of the park, had crews on it for almost two months.

Fire records are available for the park since the early 1920s. Fires generally fall into one of two categories: caused by smokers or caused by eruptions.

Prior to 1960 most fires were smoker-caused. None were started by eruptions. These were generally small (only two larger than two acres) and occurred near roads. C.C.C. workers and aircraft observers on the Hilina Pali Road contributed to the problem during the late 30s and early 40s.

Recent volcanic activity before 1960 was confined within Halemaumau or on the barren upper slopes of Mauna Loa, where no fires could be set. Since then a number of lava flows have occurred through forest and grassland, especially on the eastern rift of Kilauea. Five large and several smaller fires have been set by these flows. The other large fires in this period have been man-caused. The following table summarizes fire records for the park from 1924 to the present time:

FIRE OCCURRENCE, HAWAII VOLCANOES NATIONAL PARK - TABLE 2A

Date	Name or Location	Size	Cause	Cover Type
2/12/24	Mauna Loa Trail	2.3 a.	Campfire, smoker	Grass, koa
7/24	Mauna Loa Trail	?	Honey-hunters	Koa
8/31/29	Bird Park	6 sq. ft.	Smoker	Grass
3/27/31	Bird Park?	34 a.	Smoker	Grass, brush
6/13/31	?	.25 a.	?	Grass, ferns
5/20/32	Kipuka Kulaio	85 a.	Smoker	Grass
7/21/32	Mauna Loa Trail 5,500 f.	40 a.	Smoker	Grass, koa
7/6/36	Mauna Loa Trail	3,000 sq. ft.	Smoker	Grass
7/11/38	Hilina Pali	20 sq. ft.	Smoker	Grass, ohia
9/19/38	Hilina Pali?	9,036 sq. ft.	Carelessness	Grass, koa
8/18/39	Hilina Pali	200 sq. ft.	Spark from trash fire	Grass
5/24/40	Hilina Pali	2.1 a.	Smoker	Grass
4/29/42	Hilina Pali	.05 a.	Smoker	Grass
7/1/42	Keauhou	.8 a.	Spark from trash burning?	Grass - Burning on Keauhou Ranch
7/1/43	K.M.C.	.8 a.	--	Grass, brush
7/8/43	Steam Flats	575 sq. ft.	Smoker	Grass
8/25/43	Hilina Pali	1 a.	Campfire	Grass
6/10/45	Steaming Bluff	.44 a.	Smoker?	Grass, ohia
7/21/47	Sulphur Banks	.002 a.	Smoker	Grass
11/7/54	Mauna Loa Strip	50 a.	Smoker?	Grass, brush - began on Keauhou Ranch
7/16/55	Bird Park Picnic area	--	Camper	
7/4/57	Kapapala	800 sq. ft.	?	Brush
1/24/61	Kilauea Iki	2 a.	Eruption-lava	Ohia, fern
2/4/61	Sulphur Banks	--	Smoker	Grass
12/62	Puu Huluhulu	--	Eruption	Grass, ohia
6/17/64	Steam Flats	.5 a.	Smoker?	Grass
3/18/65	Makaopuhi	Few a.	Eruption	Grass
7/22/70	Kipuka Nene	1,900 a.	Camper?	Grass, ohia, brush
8/13/70	Kealakomo	3,000 a.	Eruption	Grass, mixed forest

Date	Name or Location	Size	Cause	Cover Type
5/71	Kipuka-Pepeiau	600 a. ?	Lightning	Grass
8/5/71	?	8 a.	Machinery	Grass
8/14/71	Waldron Ledge	65 a.	Eruption	Ohia, brush
6/23/72	Poliokeawe Pali	6 a.	Tracer	Grass
8/1/72	Naulu	3,525 a.	Eruption	Mixed forest
8/13/72	Kipuka Nene	8 a.	Boy Scout	Grass, ohia
5/5/73	Hiiaka	585 a.	Eruption	Ohia, shrubs
8/31/73	Kamoamoa	1.5 a.	?	Brush piles - cleared by YCC
9/10/73	Namakani Paio	.1 a.	Campfire	Grass, brush
9/29/73	Hilina Pali	8.5 a.	?	Grass, few trees
11/10/73	Pauahi	291 a.	Eruption	Ohia, uluhe, grass
7/19/74	Puhimau	850 a.	Eruption	Ohia, uluhe, grass
8/13/75	Six Tanks	1,460 a.	Ranching Activities?	Grass, Pukiawe, aalii, koa
8/4/76	Halape	35 a.	YCC debris burn	Grass, lantana
7/31/77	Namakani Paio	500 a.	Camper?	Ohia, shrubs

C. Fire Potential

1. Seasonal Changes

Fires have occurred in Hawaii Volcanoes National Park in every month except October, according to available records. About one half of all fires have taken place in the months of July and August.

Much of the growth in Hawaiian plants occurs during the wet season (winter and spring months). Growth has essentially stopped in some species by early summer. Grasses then dry out, leaving a large quantity of highly flammable fuel. This is most noticeable in the coastal lowland, submontane seasonal and to some extent the montane seasonal areas of the park. Some species drop most of their leaves during late winter. Other trees, among them koa and ohia, lose small numbers of leaves continuously. With dry summer and fall conditions, this layer of leaves become extremely flammable. This behavior is most noticeable in the montane and submontane seasonal types. Such leaf fall is extensive in the montane rain forest, but the litter generally does not present a hazard because of moist conditions. In extreme drought, it does of course, become a problem.

2. Influence of Exotic Feral Animals

The park's native ecosystem has been significantly affected by the long-term presence of feral goats and pigs. These non-native animals were well-established long before the park was created in 1916. It is not clearly known what the character of the vegetation and associated birds and insects was before the introduction of goats and pigs. Nevertheless, clues such as remnant native species, historical descriptions, and exclosure studies indicate that the frequency and diversity of native species have been reduced drastically in many areas of the park.

Goats

For over 100 years, goats have occupied the subalpine, montane seasonal, submontane seasonal and coastal lowland regions of the park. Continually high populations kept grass, forbs, and woody shrubs closely cropped, making fire unlikely even during extreme dry periods. Fuel that would normally accumulate was consumed.

Therefore, many areas, particularly the lowlands, remained free of fire while goats inhabited the range. In 1972, a systematic goat reduction and fence construction program was begun which has made the park virtually goat-free. As a result vegetation is recovering. Native species such as awikiwiki and morning glory are becoming more abundant and successfully competing with many browse-resistant exotic plants which had the advantage when goats dominated the ecosystem. Many plant communities, however, are still largely exotic and in the early stages of succession. It is not certain what the long range trends will be, but as vegetation recovers fuel is increasing, making the potential for wildfire much greater than before.

Pigs

Pigs occupy all except the very driest areas of the park, but they are in greatest abundance in the montane seasonal and the montane rain forest regions. Their rooting disturbs understory plants, inhibits regeneration of some species, generally allows the forest vegetation to dry more quickly than normal, and encourages the establishment of exotic plants. As a result, the more succulent vegetation in the rain forest is depleted while flammable exotic species are more prevalent. This contributes to a higher fire potential than would be true without pigs. However, because pigs are primarily found in the wetter areas, their overall role in relation to fire management is minor. A control program has reduced pigs in accessible areas, and there will probably be increased pig control activity park-wide in the future.

3. Influence of Exotic Plants

Exotic plants markedly influence the ignition, spread, and effect of fire on native ecosystems. This greatly complicates fire management at Hawaii Volcanoes.

Over 400 exotic plant species have become established in the park. Many of these occupy niches never filled by natives while others compete directly with native species. Disturbance by feral animals has permitted some to gain a foothold as well as contributing to their spread. Studies have shown that as herbivore pressure is relieved, some exotic species become less common.

This is an encouraging sign as direct control of most exotics is not feasible. Fortunately, a large number of these have minor impact on the maintenance of native ecosystems. A few exotics, however, seem to have the potential to dominate park ecosystems. For some species herbicidal or mechanical control is feasible, and direct action is warranted. These include:

Guava	Castor Bean
Lantana	Ekoa
Christmasberry	Tibouchina
Silky Oak	Blackberry
Wild Olive	Faya Tree
Cactus	Fountain Grass
Eucalyptus	Banana Poka
Kiawe	

Exotic grasses such as broomsedge and molasses grass for which control is not feasible pose the most serious problems in fire management. They have become common understory plants in the ohia forests. As a result, fires start more frequently, burn with greater intensity, and do more damage than they normally would in the absence of the grasses.

What is more, following a fire these grasses regenerate quickly, creating a higher fire potential than existed originally. Because of this phenomenon, the concept of prescribed burning to decrease fuel has limited application at Hawaii Volcanoes.

In general, it appears that native species will compete and reduce the frequency of the exotic grasses over a long period of time, providing that fires and feral animals--particularly goats--are kept out. Thus when there is doubt as to how the fire-exotic plant factor will influence native ecosystems it is probably prudent to err on the side of fire suppression until there is definitive research data to show otherwise.

4. Fire Behavior

Fire behavior in Hawaii, as everywhere, is dependent on fuels, weather, and topography. Under ordinary circumstances, many areas of the park, particularly rain forest and recent lava flows, will not burn. On the other hand, vast areas of grasslands may be expected to support rapid combustion during all except the wettest winter

months. In between these extremes are large areas of shrub and forest areas which will burn with an intensity directly proportional to the stage of drought existing at the time.

Crowning can and does occur where the forest canopy is closed, or even in a relatively open canopy where strong winds are blowing. Gusty summer tradewinds can also cause spotting of up to 1/2 mile or more. More typical, however, is a relatively slow burning, persistent ground fire which may flare up in small trees or brush, and may burn for days, or weeks in roots and subsurface organic material. Where large amounts of pukeawe, aalii, and/or uluhe are present, most fires can be expected to burn hot and spread rapidly. However, many instances of a hot fire burning into dense uluhe and then rather abruptly going out have been observed, apparently due to relatively high moisture conditions deep within and beneath dense patches of this fern.

There is much to learn concerning fire behavior in various vegetation types within the park. For this reason, all major man-caused or natural fires will have a fire behavior observer assigned whose only responsibility will be to monitor and record fire behavior as it occurs.

5. Man-Caused Fires

Over the past 50 years a majority of the fires within the park have been started by man's carelessness. Of the 26 known man-caused fires, 15 or 58% were due to smokers and five or nearly 20% were from campfires. With increasing visitation and backcountry use the potential for man-caused fires is even greater today.

The fire problem in recent years has been increased by the reduction of goats and the subsequent prodigious growth of introduced vegetation. Among the exotic plants, broomsedge appears to be one of the more aggressive and opportunistic plants. This light flashy fuel, together with molasses grass, natal redtop grass and other exotic weeds, blankets extensive areas in the montane seasonal and coastal lowland zones. Roadside and trails through these areas have become zones of high fire hazard.

During fire season the lands adjacent to the Mauna Loa Road, Chain of Craters Road, Ainahou Road, Hilina Pali Road, and Kalapana are all

high fire hazard areas. All types of visitor use into these areas become a potential hazard. A careless smoker or an unattended open fire could lead to a major fire due to the type and abundance of fuel. The use of mechanized equipment by park personnel is also a hazard, as sparks from a motor can ignite light fuels.

Another potential ignition source exists in late model vehicles equipped with catalytic converters. This emission control device generates sufficient heat to ignite light fuels. Off-road travel or the mere turning around of a light vehicle in dry grass may lead to a fire.

Deputized hunters operating in various isolated sections of the park under the feral animal control program are another potential source of man-caused fires.

6. Monitoring of Fire Danger

Two weather stations were installed in the park in the spring of 1976 to monitor fire weather conditions. They have become part of the statewide network of observation stations used to determine the current fire danger rating, which is modeled after the U.S. Forest Service's National Fire Danger Rating System.

Temperature, wind speed, dew points, cloudiness and 24-hour precipitation are measured at the 5,500' level on the Mauna Loa Strip Road, and the 3,300' level on the Hilina Pali Road. Data is relayed to the National Weather Service in Honolulu which in turn prepares forecasts of the next day's fire weather. These will form the basis for possible closure of areas, restrictions on campfires and smoking, patrol assignments, and other presuppression planning.

These locations were chosen because of the fuel types present, the degree of public use and associated ignition risk, and relative ease of collecting daily measurements.

D. Major Ecosystems of Hawaii Volcanoes National Park

Hawaii Volcanoes National Park is the youngest area of the United States. The park is spread over 344 square miles (220,345 acres) of rugged lava terrain from sea level up over the dome shaped tops of two active volcanoes; Mauna Loa (13,680') and Kilauea

(4,090'). This youthful area is surfaced with relatively recent lava flows of varying ages and, consequently, is covered over with vegetation that is both old and new in its respective successional stages.

The park has a wide range of climates over relatively short distances, from the shoreline to the summit of Mauna Loa, which results in formation of several bio-ecological zones of vegetation. These zones or ecosystems, as mapped and described by Mueller-Dombois and Fosberg, are based on elevation and climate and consist of the following:

1. Alpine (13,680' - 8,500' elevation)
2. Subalpine (8,500' - 6,700')
3. Montane Seasonal (6,700' - 3,800')
4. Montane Rainforest (3,800' - 2,000')
5. Submontane Seasonal (2,000' - 1,000') and
6. Coastal Lowland (1,000 - sea level)

These ecosystems are delineated as fire management units (see Fig. 1). Detailed U.S.G.S. topographic maps with known locations of rare and endangered plants, recent lava flows, and other information useful for fire planning purposes are kept in the Chief Ranger's Office.

1. Alpine: (8,500' to summit) Mauna Loa

   This area need not be considered in a fire management plan. The Alpine zone consists of the upper slopes of Mauna Loa which are largely unvegetated lava, pumice and cinder substrates. Between about 8,500' and 10,000' there are widely scattered gnarled, low-lying ohelo and puhiawe shrubs found only in cracks. Scattered bunch-grasses are found in the isolated areas of cinder and pumice but none of the above vegetation types could carry fire.

2. Subalpine: (6,700' to 8,500')

   In the Subalpine zone between about 8,000' to its upper limits at about 8,500' the ground is barren enough of vegetation to not be of concern in a fire management plan.

   Below about 8,000', however, attention must be given to limited fire potential. At about 8,000' is what can be considered tree line. Ohia appears as a full grown tree although individual trees are scattered widely about

100 to 200 yards apart. Denser growths of shrubs and grasses grow beneath each tree due to fog drip. Fires at these altitudes and in these vegetation types would probably be restricted to only one or a few adjacent clumps.

Ohia and mamani occur together between about 6,700' and 7,500' and grow on older weathered a'a flows. At these elevations the two species grow closer together with individuals from 10 to 50 yards apart. Trees average about 15' in height. Fires in these areas would likely be restricted to one or a few clusters of trees and understory.

3. Montane Seasonal: (6,700' to 3,800')

Below about 6,700' down to 3,800' shrub clumping beneath individual trees becomes less characteristic as trees grow closer together and shrubby vegetation fills in between trees. This is the beginning of scattered koa colonies and shrubs which dominate the landscape. Ferns and grasses are much more abundant between shrubs and trees and over most of the terrain below 6,700' there is little barren ground exposed--except for a'a flows. This area of the Mauna Loa Strip has very high fire potential.

Along the Strip as ash soil is the dominant substrate between about 4,000' to well over 6,000' and averages about 10" in depth over a'a and pahoehoe lava flows. These occur only occasionally as outcrops, except for the Keamoku a'a flow which is of sufficient size to be useable as a fire break.

Between about 4,000' and 4,200' at the base of the Strip are two very important kipukas with a number of rare and endangered plant species. These are Kipuka Ki and Kipuka Puaulu. Within the two kipukas the taller trees are koa, ohia and soapberry which reach up to 100' high to form the upper canopies. Beneath, there is a well developed secondary tree layer up to 40' in height comprising a number of species. The substrate is deep ash and pumice soils which supports a number of fern, grass, and other ground cover species.

Within the kipukas the following species can be considered rare or endangered.

Clermontia hawaiiensis var. hawaiiensis (ohewai)
Clermontia peleana
Hibiscadelphus giffardianus (hau kuahiwi)
Hibiscadelphus hualaiensis (hau kuahiwi)
Kokia drynarioides (kokio)
Gouldia sp. (manono)
Pelea hawaiiensis
Pelea zahlbruckneri (manono)
Zanthoxylum dipetalum var. geminicarpum (a'e)
Zanthoxylum hawaiiense var. citriodorum (a'e)
Zanthoxylum maviense var. anceps (a'e)
Nothocestrum breviflorum var. breviflorum (aiea)
Nothocestrum longifolium var. rufipolosum (aiea)
Eurya sandwicensis (anini)

Within both kipukas are open forests and/or savannahs with tall, dense growths of grass and fern which can be extremely flammable. Surrounding the two kipukas are boundries of more scattered trees and grass on more recent lava flows but the ohia, koa, shrubs and grasses are spaced close enough to carry fire easily into the kipukas. In the denser forests within the kipukas, where the upper canopies shade out ground cover species, fires would probably be less intense but it is likely that fires could progress completely through both kipukas under optimum conditions for fire.

Between Kipuka Puaulu and the Kilauea Military Camp there is an abrupt change in the Montane Seasonal forest to more open stands of ohia with individual trees up to 30' tall. Scattered between the trees are low lying growths of ohelo, pukiawe, aalii and other shrubs and abundant grasses. This vegetation type could carry fire easily.

In the vicinity of the Military Camp there is a broad transition area where climates change rather abruptly from a summer-dry to a more humid climate of higher rainfall. In this transition area the tree canopy is almost pure ohia mixed with tree fern understory and occasional matted thickets of uluhe. This forest goes immediately into a Montane Rain Forest near park headquarters.

4. Montane Rain Forest: (3,800' to 2,000')

Between park headquarters down to about 2,000' along the northeastern part of the park is

the dominant Montane Rain Forest area. It is characterized by pure stands of relatively even sized ohia trees up to 60' high. A distinct understory layer is formed by tree ferns and other trees up to 15' high. In many places the understory becomes an almost impenetrable thicket of uluhe fern.

Because of a lingering dampness through the summer season, even when there is less rainfall in the rain forest, the interior portions of the forest would probably not carry fire. It is probable, however, that fires outside the rain forest would burn into the outer fringes of the forest in more open areas of grass and fern.

The following are rare or endangered species of concern within the rain forest:

Cheirodendron trigynum (olapa)
Tetraplasandra hawaiiensis var. hawaiiensis (ohe mauka)
Clermontia hawaiiensis var. hawaiiensis ('oha-kepau)
Clermontia peleana
Cyrtandra giffordii (ha'i-wale)
Cyrtandra lysiosepala var. sysiosepala
Cyrtandra paludosa
Cyrtandra platyphylla var. hiloensis
Cyrtandra ramosissima
Phyllostegia floribunda
Stenogyne rugosa var. subulata
Stenogyne calaminthoides
Stenogyne sessilis var. wilkesia
Labordia hedyosmifolia var. kilaueana (kamakahala)
Labordia hedyosmifolia var. magnifolia (kamakahala)
Ophioglossum consinnum
Peperomia cookiana (alaalawahinui)
Peperomia expallescens var. brevipilosa
Aspenium fragile var. insularis
Gouldia sp. (manono)
Nothocestrum breviflorum var. breviflorum (aiea)
Nothocestrum longifolium var. rufipolosum (aiea)

5. Submontane Seasonal - summer dry: (approximately 2,000' to 1,000')

All along the pali areas of the park from west to east between about 2,000' and 1,000' there is an extremely open forest type, principally of ohia trees, where trees grow singly or in small groups and in some cases form kipukas.

Trees grow in height up to about 20'. Shrubs are not common in the west-central areas--due probably to the many decades of goat browsing--but tall, dense stands of grass extend through this area all the way up to the Ka'u Desert in the western portion of the park, and above 3,500' in the east-central portions of the Chain of Craters Road.

In the western portions there is an abrupt boundary line of grasses on the north fringed by barren lava flows and ash dunes in the Ka'u Desert. Fires in this region going upslope would burn themselves out on reaching the desert.

In the east-central portions--east of the Ka'u Desert--grasslands are mixed with some shrubby species including lantana, guava, aalii and pukiawe--all are of high fire potential. In these areas above the palis is an open ohia/grassland forest which grades upward into the Montane Rain Forest above about 2,000'. Trees are spaced about 15-30' apart. Over much of this area pahoehoe lava crops out at the surface and fine soil occurs in cracks.

In the eastern portions of the Submontane Seasonal area pahoehoe outcrops tend to become hidden in vegetative cover due to higher degrees of weathering (more ash-derived soils), and a somewhat higher rainfall which helps support more vegetation. Here the shrub components begin to dominate over the grasses and in places form almost impenetrable thickets.

Throughout all of the Submontane Seasonal dry summer vegetation types there is a high fire potential because of drought conditions in warmer months and the density of grasses and shrubs.

In isolated dry forest kipukas the following rare or endangered species can be found:

Nototrichium sandwicensis var. macrophyllum (kului)
Rauvolfia remotiflora (ha'o)
Reynoldsia hillebrandii (ohe makai)
Tetraplasandra hawaiiensis var. hawaiiensis (ohe mauka)
Bidens skottsbergii var. skottsbergii (kookoolau)

Sesbania tomentosa var. tomentosa (ohai)
Scaovola kilaueae var. kilaueae (naupaka)
Stenogyne angustifolia var. angustifolia
Pleomele aurea (halapepe)
Kokia drynarioides (kokio)
Pittosporum confertiflorum (hoawa)
Pittosporum terminalioides var. macropus
Alphitonia ponderosa (kauila)
Bobea timonioides (ahakea)
Neraudia ovata (oloa)

6. Coastal Lowland: (Sea level to approximately 1,000')

From west to east the Coastal Lowlands go from summer drought conditions to humid. There are no really significant variations in elevation which change the nature of the vegetation and the mean annual temperature is rather constant.

The Coastal Lowland is predominately a grassland comprised of lovegrass, pili grass and molasses grass interspersed with various shrubs. Scattered through it are occasional ohia trees, especially in the eastern portions, growing on weathered a'a lava. Intermingled with the ohia/a'a type are expanses of pahoehoe/grasslands where only grasses can grow in the thin soils overlying pahoehoe, or in cracks. Rare or endangered plant species in this unit include:

Nototrichium sandwicensis var. macrophyllum
Rauvolfia remotiflora (ha'o)
Reynoldsia hillebrandii (ohe makai)
Bidens skottsbergii var. skottsbergii (kookoolau)
Capparis sandwichiana var. sandwichiana
Euphorbia olowaluana var. olowaluana (akoko)
Canavalia kauensis (awikiwiki)
Sesbania tomentosa var. tomentosa (ohai)
Pittosporum terminalioides var. macropus (Hoawa)
Portulaca hawaiiensis
Portulaca sclerocarpa

In the eastern portions of the Coastal Lowland grasslands become a mixed vegetation with shrubs 6 to 15' tall with crowns just touching one another. Here are mixed forests of such trees as mango, kukui, palms, pandanus and others, but for the most

part they are interrupted in distribution and restricted to intermittent stands of trees. Dominant species of trees may vary from stand to stand.

E. Probable Effects of Fire in Major Ecosystems

(Proposed fire management actions are summarized by units in Table 2 which follows this discussion.)

Subalpine

No recent fires have occurred in this region. Fire potential is low. The ecosystem is primarily native. Fencing along the lower sections, together with a control program has reduced the number of goats in the area, but there will continue to be some influx from adjoining lands until a high-elevation (6,000' to 8,999') boundary fence is constructed. The altitude and cool temperatures have precluded the invasion of many exotic plants. Silversword is believed to be a missing component. Fire that could occur here would do little damage to native components. Fire would be isolated and confined to relatively small kipukas. Scrubby mamani, koa, and ohia would only be minimally damaged and if burned severely at the trunk, they would probably regenerate from root sprouts. A'ali'i, pukiawe, ohelo, and mountain pilo would regenerate well. Native birds of the area--the creeper, omao, nene, and pueo would be relatively unaffected by fire in the region.

Montane Seasonal

Parkland in the Montane Seasonal unit consists of a relatively narrow (1/2-1/2 mile wide) strip bordered on both sides by State land leased to privately owned ranches. The often high hazard within this unit of the park is thus compounded by the existence of large acreages of grasslands adjoining the park.

A high percentage of the flora in this ecosystem is native. Two large fires have occurred here since the park's existence. Most of the native plants in areas above Kipuka Ki will probably regenerate. Koa, mamani, a'ali'i, pukiawe, and ohia are fire tolerant species. There are several native and exotic grasses which will reinvade quickly following a fire.

Blackberry is somewhat of a problem, but it thrives under disturbed conditions, and native species will compete with it in the absence of feral animals. Herbicidal spot treatment of blackberry may be necessary to curtail its spread into burned-over areas.

Mamani trees are particularly important to the i'iwi, apapane, and amakihi, native birds of the area. Most mamani trees grow on sparsely vegetated a'a flows, and by virtue of this they are naturally somewhat protected from fire. If possible, fire fighting efforts should try to protect these old mamani trees by using men and hand tools at the edges of the a'a flows in an attempt to keep the fire from spreading across and through the a'a. Above all, bulldozers should not be permitted to knock down mamani tree pockets. Bulldozers should be kept off the a'a.

Kipuka-Puaulu and the Kipuka Ki are botanical treasures which should be vigorously protected from fire. Many irreplaceable, rare, and endangered species of plants occur here. These kipukas are also important habitat for several native bird species, and their destruction by fire would have considerable adverse effects on their populations.

Special presuppression measures have been taken in these areas. In 1976, a 12' wide, 3-mile long firebreak was bulldozed along the park boundary (outside the park) as a means of reducing the possibility of wildfire entering these kipukas from adjacent ranch land, as happened during the Six Tanks fire of 1975. Additional measures, such as fuelbreaks completely surrounding these kipukas, and special closures during extreme conditions of fire hazard are under consideration for the protection of these unique areas.

Montane Rain Forest

Fire potential in this region is low because of the persistent dampness and lack of volatile fuels; however, during an exceptional dry period the forest will burn. Exotic plants such as ginger, strawberry guava, fushia, Japanese anemone, and broomsedge are problem understory species. Tibouchina and faya tree, however, pose a more serious threat to native ecosystems. Faya tree is particularly menacing since it is already widespread in much of the area. It

does not easily invade undisturbed rain forest, but it comes in quickly following a fire. Faya tree has the capacity to grow into impenetrable thickets where virtually all native forms cannot survive. For this reason alone, fire should be suppressed in this region. Following wildfires which do occur, faya tree control using spot herbicide treatment is necessary to give natives a chance to reestablish themselves and compete. Broomsedge is also a problem invader following a fire. Successional trends in the rain forest can be expected to cause broomsedge to become less abundant, but this takes decades and in the meantime, the presence of this grass will greatly increase the likelihood of another fire in the same area.

Most native plants will survive and reestablish themselves following a fire. Ohia, ilex, and sandalwood will resprout from the roots. Birdlife is not expected to be affected to a great extent since extensive fires are rare due to persistent dampness. Lava-generated fires normally do not spread more than a few feet laterally from the flow. In general, because of the potential for invasion by exotic plants and alteration of native ecosystems, fire should be suppressed using hand tools only (no bulldozers) unless life and property are at stake.

Submontane Seasonal

This region has very high fire potential during June through November because of the dry, frequently windy conditions. Several large fires have occurred here in recent years. Much fuel is accumulating in the absence of goats, and their past disturbance of understory has contributed to the invasion of exotic grasses of which broomsedge and molasses grass are widespread and extremely flammable. Fires burn hot through the area and high mortality of old growth ohia results with no subsequent resprouting. Shrubs such as a'ali'i and pukiawe regenerate following a fire. Mamani is quite fire tolerant, vigorously sprouting from roots following a fire which burns the trunk. Many of the rarer trees are located on more sparsely vegetated a'a where fire burns much less quickly than in the heavy fuel soil. Several individual rare or endangered plants should be protected if possible. These include kauila, naupaka, ahakea, halapepe, hoawa, and hame. These specimens can

be pinpointed on a map and fuel removed from their base periodically or when there is danger of fire overrunning their locations.

Guava, faya tree, and lantana are exotic plant species which pose problems. Guava resprouts and reinvades burned over areas east of Naulu forest. Faya tree is established in the Ainahou and the kipukas above Poliokeawe Pali and becomes more widespread following a fire. It burns but sprouts vigorously from the roots. Herbicide control is necessary following a fire to prevent its complete takeover of an area where natives will only regenerate slowly. Lantana has invaded with help of goats because of their basic dislike of it. It is being controlled to some extent by various insects. Indications are that without goats, it will become less prevalent by virtue of successional competition. How it is influenced by and responds to fire is unclear.

This region of the park is involved in the park planting program. Thousands of mamani, naio, and other native species have been planted in recent years to restore the Ainahou Ranch which was acquired in 1973 by the National Park Service. It is hoped that native plantings will lower the fire potential and provide native competition to exotic plants. Upper Ainahou contains a fine ohia-mamani forest and considering the presence of unnatural understory grasses which would guarantee a hot fire, fire should be prevented and suppressed if at all possible.

Native birdlife includes apapane, amakihi, pueo, and i'o. The death of old growth ohias would have serious harmful effects on these birds.

The Ainahou area contains four nene enclosures (part of a nene reintroduction program) with breeding adults and goslings. Fire should be kept from these pens and the birds removed at the first sign of danger.

Throughout the region there are many natural fire breaks, i.e., palis, lava flows, and dry streambeds, which can be used to advantage in fighting fire. Native ecosystems have been so highly altered here that it is difficult to determine the effect fire will have; for this reason, fires should be fought gently, using men with hand tools operating at natural fire breaks to try to impede the fire's spread. Native values in this ecosystem do not warrant the extensive scarring of the landscape with bulldozers.

Coastal Lowland

Historically, this region has recived the heaviest goat pressure and with that pressure relieved, fuel is accumulating in many areas, although much of the landscape is barren lava or very sparsely vegetated and will not sustain a fire. Greatest fire potential is in the Kalapana section on the east and the Keauhou-Kaone area in the mid-section. Kalapana has an abundance of native shrubs and small trees, including lama, alahee, and akia which are common. The rarer ohe and wiliwili are found in isolated pockets, primarily on a'a. Near the Kalapana boundary, the climate is fairly wet and progressively grades drier to the Ka'u boundary. Because of the wetter climate, the fire potential in Kalapana is not as great as in the Keauhou-Kaone area, which is composed chiefly of exotic grasses as well as non-native keawe and ekoa trees which are targets for control. Other problem exotic plants which are confined to Kalapana include Christmas berry, guava, and lantana.

The Kaone area, which is recovering from extensive goat damage, is the site of a lowland nene enclosure which should be protected from fire if possible. Pueo occur in the area also,but probably will be unaffected by fire. Native plants such as awikiwiki and morning glory are becoming more common at Kaone. Their response to fire is largely unknown, but these plants appear to be more succulent and less flammable than many of the exotic grasses and woody shrubs which still dominate the area. A one-half acre ekoa patch has been the object of concentrated control efforts but this hardy weed tree persists.

Further west is Kukalauula Pali area which is also recovering from goat grazing. A nene enclosure is located here also.

Much of the coastal lowland is going to be an interesting area in which to observe what course succession will take and how effective resources management activity can be to favor the reestablishment of a great variety of native components and suppress dominating exotic invaders. For this reason, it would be desirable to keep fire out of the coastal lowlands when possible. A fire would set succession back in some locations

to a condition similar to when goats inhabited the area.

Fire, however, will travel quickly in the coastal grassland and burns are inevitable. Suppression activity should use gentle methods (hand tools only), utilizing natural fire breaks, and concentrate efforts in keeping fire out of the forested areas above the Hilina-Poliokeawe Palis.

In this Coastal Lowland, a large number of Native Hawaiian archeological sites are known but most of the acreage composing the Puna-Ka'u Historic District have not been systematically examined. Detailed maps of cultural resources have been made in coastal lowland areas north of Kamoamoa day use area and Wahaula Visitor Center which show a very dense distribution of structural units and other archeological features.

IV. IMPACT OF THE PROPOSED FIRE MANAGEMENT PLAN

Impact on the Natural Environment

How park management reacts to a given fire determines the ultimate impact it will have on the environment. Impacts can result directly from the fire itself and from methods used in its suppression. Also there could be long term adverse impact from preventing a natural fire from playing its role in the ecosystem.

Although the bulldozer is an effective fire fighting tool, the landscape is disturbed and natural features are permanently damaged. Fighting fire using only hand equipment, and taking advantage of natural barriers causes less damage to the natural environment. This method, however, is ineffective in areas of heavy vegetation and few natural barriers.

Endangered species and habitat can be destroyed by fire or by the activities taken to suppress it. Endangered plants could be in the path of fire-line builders and bulldozers. Very few individuals apt to work on a fire can identify and recognize these species; therefore there is the chance some will be lost without being detected.

Beneficial impact of the proposal is that fires will be managed by planned and predetermined action which will contribute to park objectives to preserve and restore native Hawaiian ecosystems. Suppression decisions will no longer be made primarily during a crisis situation after the fire has started. This will minimize unwise and often costly suppression activity which may do more damage than the fire itself. On the other hand, threats to important biological resources and adjacent property will be lessened by having a firm planning base from which to operate.

The long-term consequences of suppressing natural fires are not well known. Potential impacts relate to complicated interrelationships of exotic and native and successional dynamics of the various ecosystems. Research now underway will provide additional insight on this subject.

Impact on Environmental Quality

Water quality will not be impaired as a result of fire. Volcanic soils are highly porous with virtually no stream flow. Erosion from wind and water will be slight. Soil will be revegetated with grasses within a few

months of a fire. Air quality during a fire will be reduced. Northeast trade winds blow smoke and fume out to sea quickly and there are few inhabitants downwind from potential fire regions. Burning of sugar fields is a well established and frequent activity in Hawaii.

Impact on Cultural Resources

Although numerous early Hawaiian stone structures dot the park, especially in the Coastal Lowland area, fires of low temperatures would have no permanent adverse effect on the stone constructions. But the potential for Carbon 14 dating, palynological research, and archeomagnetism dating of hearths may be adversely affected by fires. Natural erosion may be increased by removal of ground cover.

Actions to Minimize Environmental Impacts

Following fire in which bulldozers are required, earth and debris piles produced along fire breaks will be graded and leveled to return landscape to its original conformation. If necessary, rare and endangered species of plants destroyed by fire will be propagated in the park greenhouse and planted to assist their becoming reestablished in the affected area. This is part of an ongoing effort to restore native ecosystems within the park.

Research shall be encouraged and conducted to determine and further understand the role of fire in park ecosystems.

Suppression by hand of wildfires burning in proximity to significant archeological and historic National Register properties should be accomplished with consultation with the Pacific Archeologist. Management fires within Historic Districts will require evaluation of effect as required in 36CFR800.4.

Unavoidable Adverse Impacts

Some landscape could be permanently altered on fires for which bulldozers are required.

Some rare and endangered species could be destroyed by fires and the activities used for suppression.

V. ALTERNATIVES CONSIDERED

Suppress all Fires at all Times by Whatever Means Necessary

With this policy, all fires regardless of location would be suppressed as quickly as possible using whatever equipment is necessary. This approach was rejected because the response needed in one ecosystem, vegetation or terrain type could be inappropriate in another. Activities to control a fire frequently would be more damaging to the park's biologic resources than the fire itself. Fire suppression costs could be unnecessarily high.

Suppress All Man-Caused Fires and Let Natural Fires Burn

This alternative was rejected because it would permit fire to endanger adjacent property to the park and permit the degradation of native ecosystems values in many areas where exotic plant infestation would cause unnaturally hot and destructive fires. Also, some invaluable native biological communities might be irretrievably damaged. Many rare and endangered plants and habitat for native fauna could be destroyed.

Prescribe Burn Areas of the Park

This alternative would attempt to prevent conflagrations which can do maximum resource damage. Park employees could set fires under specified conditions to produce a fire which would remove understory fuel and do only minimum resource damage. This technique is being used in many mainland national parks and has been found beneficial to the maintenance of natural ecosystems where natural fire has been excluded for many decades.

This alternative was rejected for the time being because not enough is known about Hawaiian ecosystems and their role with fire. The influence of feral animals and exotic plants complicate the situation. This approach must wait until more is known and the results of a prescribed burn can accurately be predicted as being beneficial to the preservation and restoration of native ecosystems.

CONSULTATION AND COORDINATION

During the development of the fire management plan portion of Hawaii Volcanoes Natural Resources Management Plan, the following sources were consulted for their knowledge, suggestions, and recommendations:

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